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Assessment of renewable energy resources potential in Oman and identification of barrier to their significant utilization

A.H. Al-Badi *, A. Malik, A. Gastli

Department of Electrical & Computer Engineering, College of Engineering, Sultan Qaboos University P.O. Box 33, Al-Khod, Muscat 123, Oman

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ABSTRACT

Oman relies on gas and oil resources fuels for almost all of its energy needs. Almost 99% of its power generation is based on natural gas. However, the country's natural gas supplies are currently largely committed, and it may become a net importer soon. Therefore, there is a need to look for alternative energy resources. This paper presents a review of the assessed potential of renewable resources and practical limitations to their considerable use in the perspective of present scenarios and future projections of the national energy for Oman. Solar and wind are likely to play an important role in the future energy in Oman provided that clear policies are established by the higher authority for using renewable energy resources. Rural Areas Electric Company has initiated solar and wind pilot projects in its concession area to confirm the performance and efficiency of renewable technologies in local conditions.

Contents

1. Introduction

The growing renewable energy market is driven by rising fossil fuel resource prices, climate change due to pollutions, concern about energy supply security, and the declining costs of different renewable energy technologies. In 2007, wind power capacity increased by a record-breaking 20,000 MW, bringing the world total to 94,100 MW which is sufficient to satisfy the residential electricity needs of 150 million people [1]. The total global wind power installed capacity reached 100,000 MW in March 2008 [1]. Germany is still the frontrunner in total installed wind power capacity, with 22,200 MW, followed by United States, Spain, India, and China [2,3]. The use of PV is still continuing increasing. The production reached approximately 7 GW in 2007. Moreover, the solar PV industry is also witnessing a boom in silicon production facilities around the world, responding to silicon feedstock shortages of the recent past years.

Oman's economy is heavily dependent on oil and gas revenues, which account for about 81% in 2006 of the country's export earnings and 48.6% of its gross domestic product (GDP) [4], as depicted in Fig. 1. Since 1967, exporting crude oil has been the

* Corresponding author.
E-mail addresses: albadi@squ.edu.om (A.H. Al-Badi), asmalik@squ.edu.om (A. Malik), gastli@squ.edu.om (A. Gastli).

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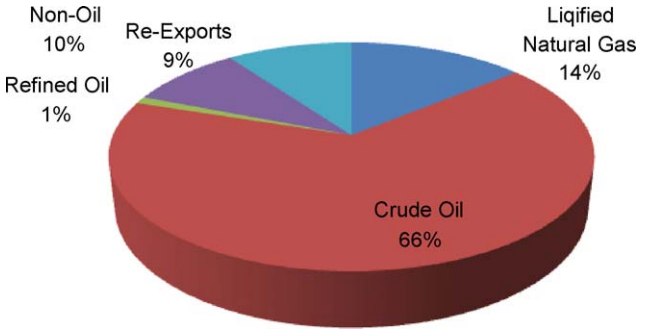

Fig. 1. Structure of merchandise exports in 2006.

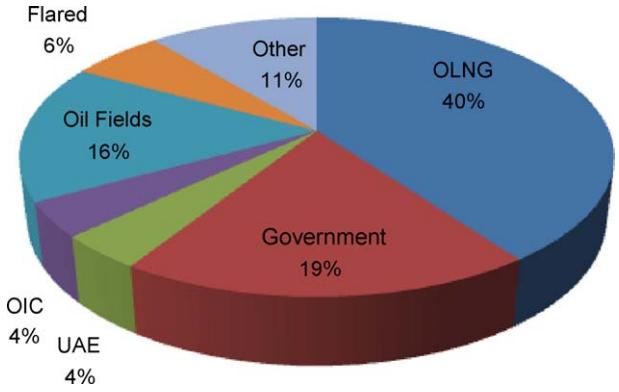

Fig. 2. Usage of natural gas in 2006 [1].

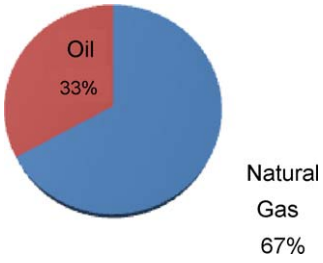

Fig. 3. Primary energy supply 2004 [1].

leading hard currency earner with an average 738,000 barrels of crude oil per day in 2006. Oman's oil fields, however, are generally smaller, more widely scattered, less productive, and pose higher production costs than in other Arabian Gulf countries. The annual production of natural gas is approximately 900,000 MNSCF per year and has been increasing over the last years. In 2006 the natural gas production was reached 1,068,888 MNSCF. The usage of natural gas in 2006 is shown in Fig. 2. All of Oman's domestic energy consumption is supplied by natural gas and oil as presented in Fig. 3.

The residential sector is the largest consumer category with its consumption taking more than half of the total system energy, as presented in Fig. 4 for years 2006 and 2007, respectively. However, the industrial sector is the fastest growing part with an annual growth rate of 14.4% in comparison to non-industrial sectors which has growth rate of 6.3% [5].

Rural Areas Electricity Company (RAECO) provides electricity and water to Oman's rural areas which are not connected to the main interconnected system or the Salalah electricity system. The growth in the customer accounts was 6.5% in 2007 and due to government's commitment to rural development; the demand is expected to continue to increase faster [6]. The percentage increase in the total power generation in RAECO for year 2007 was 12% compared with 2006 [6]. The average economic cost was estimated by the Authority for Electricity Regulation (AER) to be US$ 0.21/kWh in 2006, though at some other location in RAECO the costs are reaching US$ 0.67/kWh [7]. The diesel fuel forming around 60% of its total operating costs [6]. Because of Oman's dispersed population in the rural areas and the high cost of operating, maintenance, transportation and fuel at these locations, RAECO's costs are considerably higher than the rest of power systems in Oman. These factors present a challenge for RAECO but also opportunity to become Oman's renewable energy leader. Renewable projects at RAECO diesel power stations will have the highest return on investment and quickest payback.

In March 2009, Oman's electricity regulator has appointed international consultancy firm to assist with reviews and approval of renewable energy pilot projects which was initiated by Rural Areas Electricity Company. These pilot projects will provide information about the performance and efficiency of renewable technologies in local conditions. Moreover, these projects will also alert local and international developers to the Sultanate's significant renewable energy potential.

2. Electrical power system in Oman

The energy demand in the sultanate is supplied by the following main systems:

1. The main interconnected system (MIS) serves the majority of people in Oman (almost 500,000 accounts). It covers the Governorate of Muscat, Governorate of Buraimi, Batinah region, Dakhilyah region, Sharqiya region, and Dhahirah region. It comprises a number of power generation stations, a single transmission grid, and three distribution companies. The MIS is interconnected with the power system of Petroleum Develop-

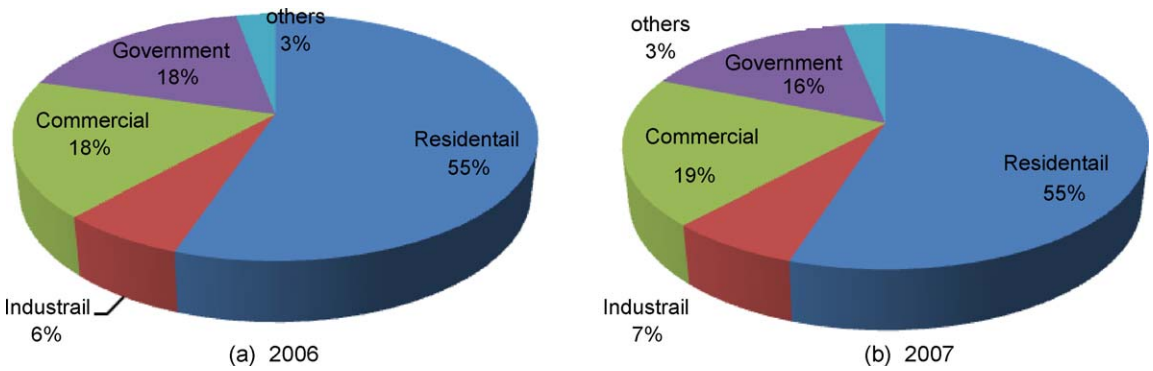

Fig. 4. Sectored energy demand in 2006 and 2007 [3].

ment Oman (PDO) by 132 kV, and will shortly be connected with Emirates power system through 220 kV link. The system interconnects seven main power plants with around 3000 MW of net generation capacity and transmits power over 220 and 132 kV lines. The fuel used to run these power plants is natural gas. The maximum power demand is expected to increase from 3031 MW in 2008 to 5348 MW by 2015 with an average increase of 8.5% per year [2]. The annual energy demand is expected to grow from 14 TWh in 2008 to 25.6 TWh in 2015. This growth is due to the increasing number of population, rising personal incomes and general economic development, and the demand from new industrial and tourism projects. Therefore, an additional power generation resources are needed for MIS every year which will reach between 2100 and 3000 MW by 2015 [5]. The total fuel requirements for power generation and water desalination are expected to increase from 184 million GJ in 2008 to about 256 million GJ by 2015 [5].

2. The Salalah system covers Salalah and surrounding areas in the Dhofar region, serving around 50,000 accounts. The electrical power is generated in Salalah by 8 gas turbine units (256 MW) and 14 diesel engines (65 MW). The Salalah system operates as an isolated system, it is expected to be connected to PDO system by 2010. The maximum demand is expected to grow from 260 MW in 2008 to 552 MW by 2015, with an average annual increase of around 11% [5].
3. The remaining of scattered rural areas of Oman is provided with the electrical power by mainly diesel generators, with total installed capacity of about 447 MW. In 2007 there was an increase by 12% in total power generation to satisfy the demand increase.
4. The main oil company in Oman (Petroleum Development Oman) has its own dedicated system of around 1000 MW capacity.
5. There are also other companies that produce power for their own needs; such as Oman Mining company, Oman Cement Company, Sohar Refinery, Sohar Aluminum Company, Ministry of Defense, Occidental of Oman, etc.

The annual demand curve reflects the climate in Oman and is highly seasonal. The average summer demand is more than double of the average winter demand, owing to the increase in residential demand during the hot weather in summer. The demand peaks typically in July reflecting the highest temperatures and intensive use of air-conditioning. The peak demand, for MIS system, reached 2773 and 2614 MW in July 2007 and 2006, respectively, as depicted in Fig. 5. For Salalah system the peak demand occurs in May, reached 232 and 253 MW in 2006 and 2007, respectively. In the future, a reduction in the demand seasonality is expected to reduce due to new large industrial loads coming on line. Daily load profile has a distinct shape. Peak hours are between 3 pm and 5 pm, and again between 11 pm and 4 am in the summer. In the winter there is a small peak hour at 8 pm.

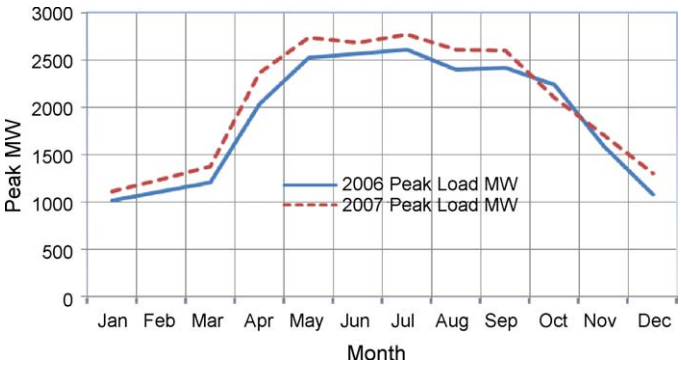

Fig. 5. Main interconnected system peak demand-2006 and 2007.

The demand projections in the future are expected to increase due to the following two main factors:

1. The increase in population, rising personal incomes, and general economic development.
2. The government policy for diversification of the country economy has resulted in new large industrial and tourism projects. New industries and tourism projects are expected to be built in different places which will require substantial power demand.

3. Renewable energy barriers and incentives in Oman

Renewable energy development is dependent mainly on political support. As long as renewable energies are not financially and economically competitive on the liberalized market, there is a need for a political support. However, this energy is expected to become progressively cheaper in the very near future.

The patchy and widely disparate patterns of renewable energy development in Oman, facing a host of policy and administrative barriers – including highly subsidized cheap electricity [8] competing with renewable technologies – as well as the lack of adequate fiscal incentives to consumers for their installation, have prevented the spread of renewable energies in the country. Flows of foreign technology and finance were also way below needs.

It is believed that there was a significant lack of trustful information related to worldwide and regional reference renewable energy applications which can lead to the identification of the technical opportunities to overcome barriers related to the cost, performance, and reliability of the systems.

Oman and even the GCC region lack accurate data and information about the potential use of renewable energies. This also constitutes a barrier to the development of this sector. Oman has so far 31 metrological stations providing measurement of ground wind speed and only 7 stations providing data on solar insolation. So far very little research has been conducted on Oman's prospect to use renewable energies such as wind and solar energies. There were no serious studies conducted by the Omani government which could clearly determine the economic and environmental benefits from the deployment of renewable energy (RE) systems in Oman. Accurate database and knowledge of most appropriate locations of renewable energy applications in the country are strongly needed. So far very few accurate data is available about Oman regarding solar irradiation and wind speed and direction. The available solar data is from mainly 7 weather stations and the ground speed wind data (at 10 m only) is from 31 stations. The data collected is very much localized into few areas and does not cover a big part of the country where very high potential of the usage of renewable energy exists especially in rural and remote areas. To help and encourage proper investment in electric power generation from renewable energy, such as solar and wind, it is important to develop such geographical maps and models which locate and evaluate the potential of the most appropriate sites for different solar and wind power technologies.

Besides, there were no country-level and regional skillful task-forces to manage renewable energy projects' development processes, establishing and reviewing rules and laws as required. It was only until 2 years ago that some such task-forces have been created and responsibilities have been assigned to the Authority for Electricity Regulation which has conducted a preliminary study to investigate the potential of using renewable energy in Oman. The Rural Areas Electricity Company has been assigned the responsibility of encouraging the implementation of small-scale projects in rural areas of the country. However, there is still a long

way to go in order to create reasonable incentives to local, regional and international investors to start the construction of some renewable energy project prototypes.

In addition, the lack of sufficient and adequate financial support to research constitutes a serious barrier to sustainable development of research in the country. The recent establishment of the Research Council in Oman is a good opportunity which also can be considered as an incentive for changing this situation. Sultan Qaboos University (SQU) as the national hub for science and technology in Oman, has already identified opportunities to boost the RE sector in the country and the region and has already started developing its education, research and networking infrastructure both locally and internationally to help the public and private companies and institutions through providing useful research and consultancy and education. Several courses and materials related to renewable energy have already been injected into some curricula to allow the formation of skillful manpower in the country and the region. Also, several RE related projects have been and are still being carried out.

However, it is still believed that Oman has been left behind, and it is very important now that political decisions are being taken to catch up with the rest of the world because Oman has now adequate intellectual and financial resources to do this. It is only until 2007 that the previous 'fear and distrust' of renewable energies on the part of Oman as an oil and gas producers country had changed into a realization that they were an essential component of their national energy supplies, as well as a global strategic option for both extending the life of oil and gas reserves and reducing carbon dioxide emissions and thus combating climate change.

Oman has signed the Kyoto Protocol, so it has to make steps towards implementing it. It is committed to do this because it is good for the environment and there are investment opportunities for clean development mechanism products. Added to this, Oman has high solar energy resources and abundant land areas for development. In addition, there are high opportunity costs of using gas for power due to capacity for further LNG exports especially under this actual rapid economic and corresponding power demand growth.

Positive investment climate, strong property rights, and low tax regimes, with established participation in the power sector from leading international firms, will provide incentives to more renewable energy applications in the near future. It is recommended that non-renewable energy policy support has to be revised and laws governing power generation regulation shall give more flexibilities and incentives to the use of renewable energies. For instance, the government has to develop policies to support investors in a large-scale solar thermal or hybrid solar thermal/natural gas plants, and also to support/increase market opportunities for small-scale solar photovoltaic.

Large-scale non-renewable energy such as the planned 1 GW coal plant in Duqm region will make it difficult for Oman to reduce its total carbon emissions. Besides, other neighboring countries such as UAE will possibly capture first mover advantages and develop regional expertise because of their recently announced subsidies and incentives for solar photovoltaic installations.

4. Renewable energy resources potential and limitation

The development of renewable energy resource technologies is an ongoing process and technologies which are not economically feasible today may very soon become relevant for Oman due to rapid technological development. Research and development activities within renewable energy have been carried out at Sultan Qaboos University by the renewable and Sustainable Energy Research Group [9] as well as by other researchers from different institutions in Oman.

Solar energy is the sole renewable energy resource which presently is utilized in Oman for heating water in tanks located on the roofs at some private houses. Generation of electricity by photovoltaic cells is used for powering street lights, public phones, water pumping system parking meters, cathodic protection system and microwave and television transmitter stations.

4.1. Wind energy

In December 1996, the Oman's first 10 kW wind-powered, electric water-pumping system was successfully installed to assess the role of wind power in pumping the groundwater [10].

The wind power in Oman is another promising renewable source for power generation in the southern part of Oman. A theoretical study with actual electric load and nearby wind speed data taken at a remote agriculture station in south of Oman showed that a 50 kW wind turbine could be installed in parallel to the existing diesel generating sets to economically justify its installation cost as energy fuel saver with a simple payback of 8.5 years and a discounted payback of 15.6 years at 10% discount rate [11]. The assessment of wind energy resources is based on the wind data measured at 26 stations at 10 m above the ground level. Five stations with the highest wind speeds were identified based on the data obtained from reference [12]. The high wind speeds are found along the coast from Masirah to Salalah during the summer period, which is also the period with the highest electricity demand. The low wind speed areas are located in the north and western part of Oman. The highest wind speeds are in the Dhofar Mountain Chain north of Salalah.

The measured annual mean wind speed at 10 m and the calculated annual mean wind speed at 80 m above ground level at each of the five stations are presented in Fig. 6. Wind turbine designs can accommodate high or low wind conditions. Wind turbines designed for low wind conditions are characterized by a large rotor swept area and an increased hub height. For wind conditions in Oman, low wind turbines are more suitable.

The study done on renewable energy resources for Authority for Electricity Regulation [13] reveals that at the present gas price of 1.5 US$/MMBtu wind energy is not economical. The wind energy at Quiroon Hariti, the highest wind potential in Oman, becomes marginally economical at a gas price of 6 US$/MMBtu. At the opportunity cost of natural gas price of approximately 3 US$/MMBtu and adding a depletion premium of 3% per annum the cost of wind energy becomes comparable to open cycle gas turbine (GT) power plants. The combined cycle gas turbine (CCGT) power plants remain cheaper, however. The comparison is made by assuming the economic life of assets (GT, CCGT and 20 MW wind farm) to be 25 years and the real discount rate at 7.55%.

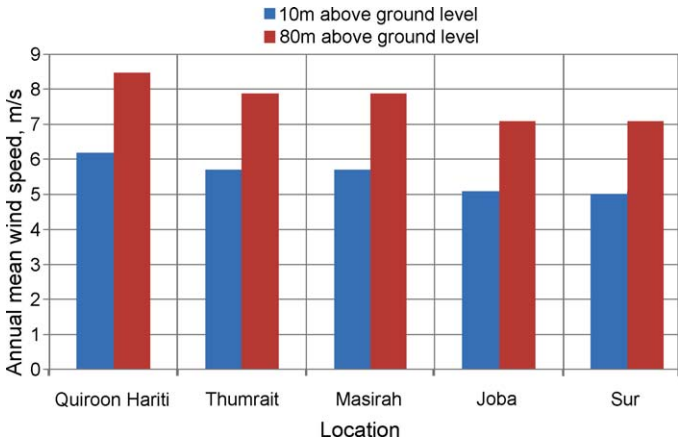

Fig. 6. Annual mean speed at 10 and 80 m above ground level at five meterological stations.

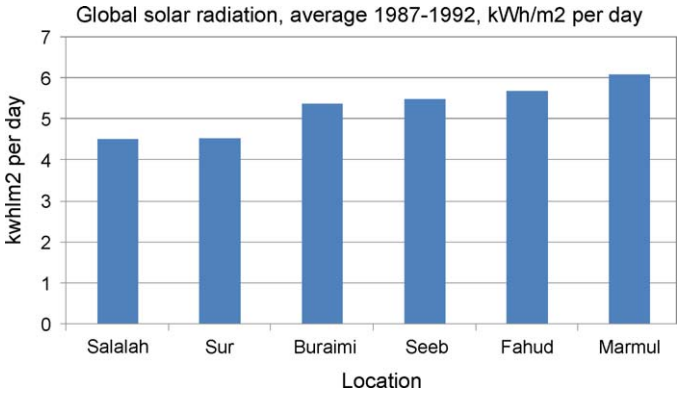

Fig. 7. Global insolation average for 1987–1992 for the six stations.

This clearly shows that wind application for large wind farms is not presently economical. However, the wind remains a suitable economic option for small remote applications [11] where the national grid is not yet extended.

4.2. Solar energy

The solar resources in Oman are among the highest in the world [14]. It is important to use data covering several years in order to estimate the long term average solar energy resources. The average global insolation data which is the sum of direct and diffuse radiation from 1987 to 1992 for six locations in Oman is depicted in Fig. 7 [15]. As shown in the figure, the solar insolation varies from 4.5 to 6.1 kWh/m^2 per day which corresponding to 1640–2200 kWh per year per square meter.

Salalah and Sur have a significant lower insolation compared with other stations; this is due to the summer rain period in Salalah and the frequent period with fog in Sur.

Relatively high solar energy density is available in all region of Oman. The total solar energy resources in Oman are enormous and can cover all energy demands as well as could provide export [13]. Generally the highest insolation is in the desert areas and the lowest is at the coastal area in the southern part of Oman.

Solar thermal power plant can be built in Oman to produce substantial amount of energy. The potential for producing energy from this technology is more or less independent on the season with a slight decrease in winter time. The consumption of energy is higher during the summer time due to the need for air-conditioning. During the winter time the surplus production can be exported to Europe where the need for energy is highest. Theoretically it is possible to power Oman by utilizing about 280 km^2 of desert from solar collectors, corresponding to 0.1% of the area of the country [14]. As a first step in this direction, the Public Authority for Electricity and Water of Oman has invited specialized international consultants to compete for a tender to provide advisory services linked to its plan to develop a large-scale solar power plant in Oman. Interested firms have until 25 May 2009 to submit firm offers for this key contract [16].

4.3. Biomass energy

Biomass is organic material made from plants and animals. When burned, the chemical energy in biomass is released as heat. Materials that are made out of glass, plastic, and metals are not biomass because they are made out of non-renewable materials. Building biogas power plants operating on crop and animal wastes in Oman is limited by several factors, such as collection of materials and availability of these materials because these are processed and used as fertilizer. Moreover, the waste water system is covering only small part of Oman, which currently is not sufficient to provide a fuel for a power plant.

However, in Oman there are several landfills which can be utilized to produce methane gas so that it can be used as a fuel source.

4.4. Wave energy resources

The wave energy in the world oceans varies from approximately 10 kW/m wavelength and up to approximately 100 kW/m [17]. The wave energy potential in the Arabian Sea is among the lowest in the world and it can be assumed that this energy cannot contribute significantly to power generation in Oman.

4.5. Geothermal energy

Temperature maps for 500 and 1500 m depths and locations of boreholes within the petroleum Development Oman concession area reveals that the highest temperature is 174 °C [18]. This is below the temperature required for directly use of the hot water for running steam power plant.

5. Conclusions

It is about time for a big change in the energy culture in Oman. It is very important now that the Authority for Electricity Regulation (AER) in Oman start providing an adequate regulatory support to the use of renewable energy in the country. Investments in renewable energy applications which offer potentially significant economical and environmental benefits, must be encouraged with tangible incentives.

The government, the AER, the Research Council, and the private sector should support development of research in renewable energies technological development and applications.

There should be some incentive to encourage people to generate energy in their houses using solar or wind energy. The AER should also discourage the usage of electrical water heater and issue regulation on using of the solar water heater.

Recently government has taken an initiative to explore the possibility of using solar thermal power. The Public Authority for Electricity and Water of Oman has invited specialized international consultants to compete for a tender to provide advisory services linked to its plan to develop a large-scale solar power plant in Oman.

Rising diesel costs and the technological advances in solar and wind technologies make it increasingly economical to substitute off-grid diesel generation with wind, solar PV, or solar thermal generation. Rural Areas Electric Company has initiated solar and wind pilot projects in its concession area to confirm the performance and efficiency of renewable technologies in local conditions. Pilot projects will also alert local and international developers to the Sultanate's significant renewable energy potential.

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